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STABILIZATION OF PHOTOVOLTAIC PANELS CELL WASTES IN BUILDING MATERIAL MATRICES

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Abstract

This is a study about the hydration process of a mixture of Portland cement and solar photovoltaic cells waste. The nature of the hydration products of different compositions of these mixtures have been evaluated, at 20º C of temperature, by means of the analysis of samples throughout x- ray diffraction and infrared spectroscopy. The total porosity and mechanical strength development of those materials was also determined. It was revealed that the presence of solar cell residue –up to 5%- in the cement matrices do not induce to the develop of new hydration products different of those from the normal hydration of the Portland cement. However, the presence of the waste induces to a reduction of the mechanical strength and an increase in the total porosity is evidenced.

Keywords: *solar photovoltaic cells, cement, hydration, microstructure, strength.*

INTRODUCTION

Photovoltaic (PV) energy is a renewable, versatile technology that can be used for almost anything that requires electricity. In the past 20 yr, research and development has advanced PV and a new generation of low-cost products based on thin films of photoactive materials (e.g., amorphous silicon, copper indium diselenide, cadmium telluride, and film crystalline silicon) deposited on inexpensive substrates, increase the prospects of rapid commercialization [2-3].

An important factor and the key in the cycle of life of PV modules is decommissioning at the end of their use, expected to last about 30 yr. Moreover, there is a concern about disposing them because they may contain minor amounts of regulated materials (e.g., Cd, Pb and Se). Options to recycle manufacturing wastes and used solar cells are recently being investigated [4-5].

This research is an attempt to explore the possible reutilization of solar cell residues from PV panels in construction materials, which cannot only provide low cost cement and concrete but also, can help to decrease environmental hazards. In this context, an experimental study of the addition of residues from the manufacturing of PV solar cells to Portland cement has been developed in order to stabilizate/valorizate this waste in Portland cement matrices.

EXPERIMENTAL

Materials

A Portland cement type I 52.5 R and a solar cell residue (SCR) obtained from the manufacturing of photovoltaic panels A-120P from ATERSA were used in this research as raw materials. A PHILIPS PW 2400 X-ray fluorescence spectrometer with a PW 2540 VTC sample changer was utilized to determine the chemical composition of the materials (see Table 1). The SCR presents 1.69% of AgO, 0.05% of PbO and 0.05% of Ni_2O. Mineralogical composition of the raw materials was determined by an X-ray diffractometer (XRD) with a Siemens D500 instrument and an FTIR- Bomem MB-120 Fourier transform infrared spectrophotometer with a frequency range of 350 to 5000 cm^{-1} were used.

Table 1. Chemical Composition of raw materials

	Al_2O_3	CaO	SiO_2	Fe_2O_3	MgO	K_2O	TiO_2
CP	5.04	63.25	19.56	3.50	1.96	0.75	0.22
SCR	13.87	0.07	84.26	---	---	---	---

EXPERIMENTAL

The solar cells residue was grinded using a Retsch disc mill. The grinded wastes were sieved trough a 0.063 mm sieve and only the particles of minor of 63 µm size were used for the study: the Figure 1 shows the received residue from Atersa and the grinded one.

Figure 1. Solar cells residue

In order to study the microstructure of these materials different pastes, with and without SCR, were elaborated. First of all, consistency tests were conducted in order to establish the appropriate ratio water/cement for pastes elaboration (UNE-EN 196–3). The initial composition of the studied mixtures is shown in Table 2.

Table 2. Initial composition of the studied mixtures

Notation	% SCR
PC	0
SCR0.3	0.3
SCR0.5	0.5
SCR1	1
SCR3	3
SCR5	5
SCR15	15

The pastes were placed in a curing chamber at 20 ± 1 ºC and RH=95 ± 2 % and were cured for up to 28 days, after that they were immersed in acetone in order to stop the hydration process of the pastes. The pastes mineralogy and microstructure of the matrices were studied by XRD and FTIR.

In order to determine materials strength, mortars, with and without SCR, were prepared with a siliceous aggregate (UNE-EN 196-1). The selected studied SCR/Portland cement ratios were: 0.3, 0.5, 1, 3 and 5%; the binder/sand ratio was 3:1 and the water/cementitious material ratio was kept constant at 0.5. The specimens were cured at 20±1 ºC and 95 ± 2 % relative humidity (RH) for 28 days. The flexural and compressive strengths of the specimens were measured as specified in European standard UNE-EN 196-1.

RESULTS

Consistency and initial and final set tests

The results of these tests are shown in Table 3. During the development of the tests it could be notice, mainly with major SCR content and at early ages of the reactions that some kind of expansion of the materials was happening.

Table 3. The results of consistency and set tests

% SCR	Water/solid	Initial set (min.)	Final set (min.)
0	0.284	150	215
5	0.287	169	226
15	0.288	175	230

Strength and total porosity

The representation of the mechanical strength of mortars at 28 days of curing time, as a function of SCR percentage is given in Figure 1. The addition of 0.3% SCR did not significantly modify the compressive strength of mortars, although a more important reduction of strength is observed for 0.5 % and higher of SCR. However, a minimum of compressive strength is achieved for mixtures with major SCR portion. Then, the presence of SCR induces to a substantial change in compressive strength compared to the specimens without admixtures.

It may be deduced from the data in Table 4 that the total porosity values show an important increase with the presence of SCR in the mixtures and major for samples with 0.5 % content of SCR. However, it is remarkable that from 1 to 5% of SCR neither content nor significant influence are observed; it is interesting to remark that with 5% of SCR the total porosity of the sample is the same that for Portland cement.

Table 4. Total porosity and Compressive strenth

% SCR	% Total porosity	MPa Compressive Strength
0	14.9	55.4
0.3	16.0	50.5
0.5	16.8	43.6
1	16.5	34.2
3	15.5	30.3
5	14.9	32.4

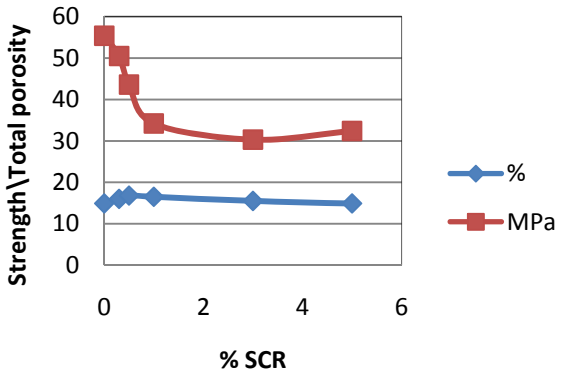

Figure 1. Total porosity and compressive strength.

Paste mineralogy and microstructure

Infrared spectroscopy

The Figure 2 shows the infrared spectrums of the pastes prepared with different dosages of SCR and cured during 28 days. The infrared spectrums of all the studied pastes had vibration bands at around 3645 cm^{-1} associated with the OH free frequency due to portlandite presence; minor relative intensity of this band was observed in samples with higher SCR content.

The infrared spectrums of the samples had vibration bands at around 963- 975 cm^{-1}, associated with the Si-O (v_3 (Si-O)) stretching vibration in the SiO_4 tetrahedra comprising the C-S-H gel. The two bands appearing between 456 and 470 cm^{-1} were attributed to the O-Si-O (v_4 (O-Si-O)) deformation vibration. The aragonite and calcite v_3 $[CO_3]^{2-}$ vibration bands appeared at 1490 and 1423 cm^{-1}, respectively, while the v_2 $[CO_3]^{2-}$ and v_4 $[CO_3]^{2-}$ vibration bands for the carbonates were observed at 874 cm^{-1} indicating some minor carbonation of samples. The anti-symmetrical stretching frecuency of the sulphate ion (v_3 SO_4) of ettringite is centred towards 1118 cm^{-1}.

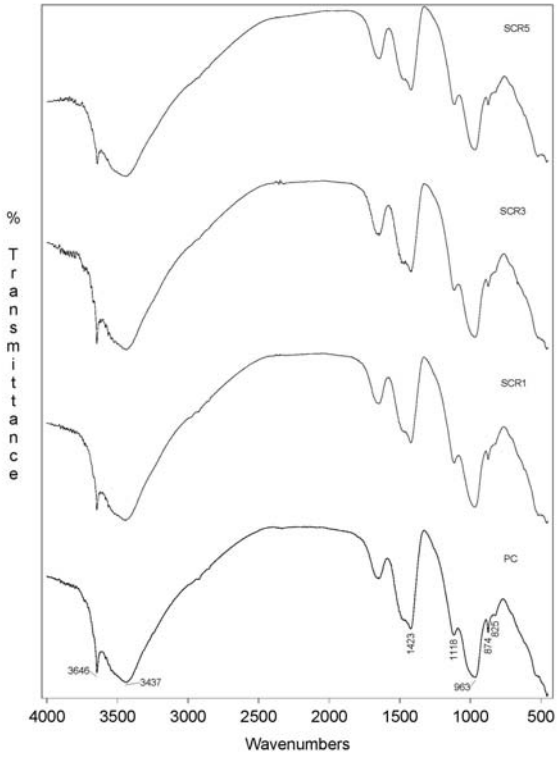

Figure 2. Infrared spectrums of samples.

X-ray diffraction (XRD)

The figure 3 shows the XRD patterns for the pastes with and without admixture and cured during 28 days. Although, the identification of the C-S-H gel through XRD is particularly difficult, the presence of portlandite and a non reacted SCR can be clearly identified. Minor portion of ettringite is detected as SCR portion increase in the studied samples.

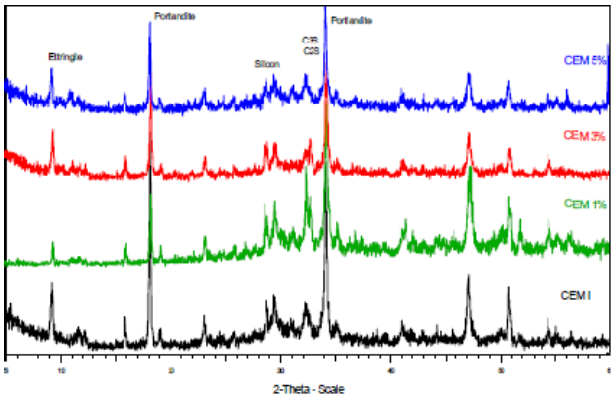

Figure 3. X-ray diffraction of samples

DISCUSSION

The studied hydration process shows that the incorporation of SCR to Portland cement matrices does not develop into different compounds of the normal hydration of Portland cement. However, it would be very interesting to make a next step in the investigation and try to follow the reactions not only at the macro and micro scale but also at the nano scale; it would be of great interest to know the probably incorporation of different elements from the SCR into the hydration products and a special effort should be done in the leaching of these matrices in order to avoid the release of hazardous compounds.

In the relation to the physical properties of these materials, this behaviors could be assigned to the reaction at early ages of the aluminum from SCR with portlandite giving to a release of hydrogen that provoke a more porous structure and having consequences in the strength development of materials. However, the presence of 5% of SCR does not modify the total porosity but the mechanical strength decrease, then it would be good to make another microstructural studies as determination of pore size distribution and scanning electron microscopy in order to clarify this results. Then, it is obvious that non structural applications can be affronted with this type of mixtures but they still present good properties and probably will give solutions to potential ongoing new purposes.

CONCLUSIONS

The use of the SCR as a component of the cement matrix induces to:

1. A substantial change in compressive strength compared to the specimens without admixtures. A decrease of 31% is measured.
2. There is an influence in the set of the mixtures and provoke a retard of the initial and final set but still it is into the standards requirements.
3. The total porosity of mixtures is influenced and decreased up to 1% for samples with SRC and it is not modified for 5%.
4. With the experimental techniques used there were not detected compounds different of that of the normal ones observed in the Portland cement hydration. Major portion of ettringite and portlandite were detected in samples without SCR.

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